National Aeronautics and Space Administration

Exploration Medical Capability Medical System Recommendations for Gateway

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Medical System Content Development - 2019

Develop clinical content to inform medical system design

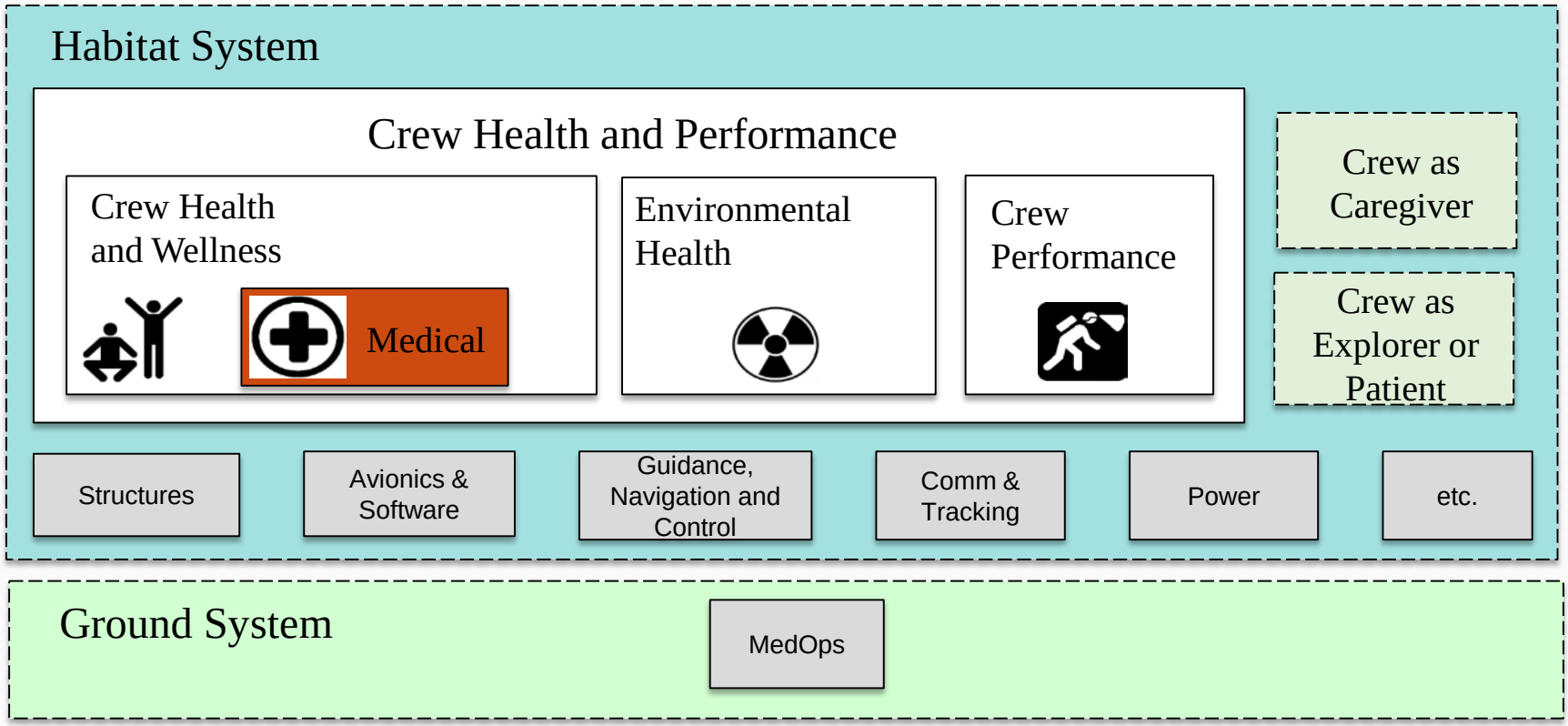
Iterate on content with wider ExMC team

Capture processes used to perform these tasks

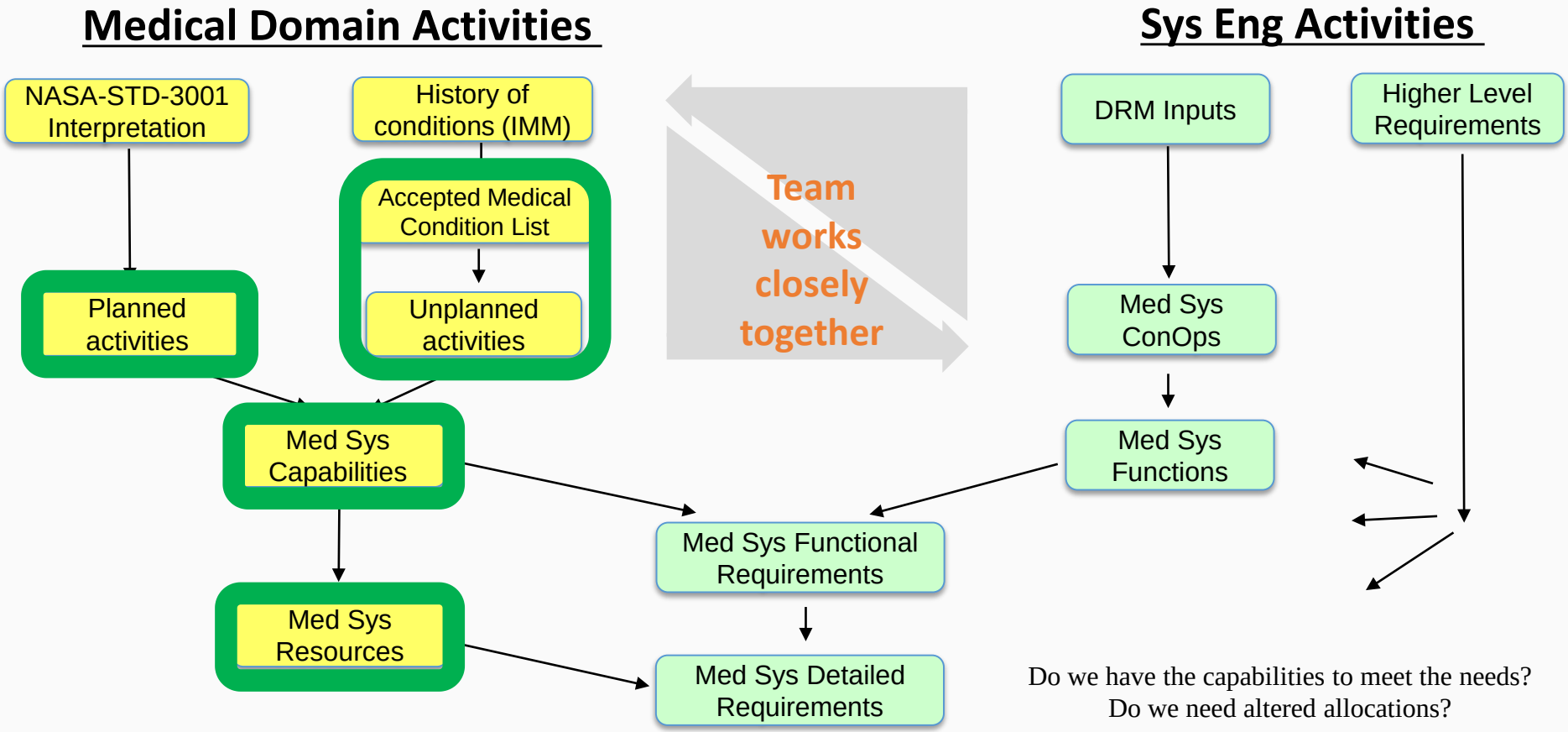
Overview of Talk

- **Medical System content development**
- **Using model content to inform system design**
- **SME collaboration to refine systems using clinical content**

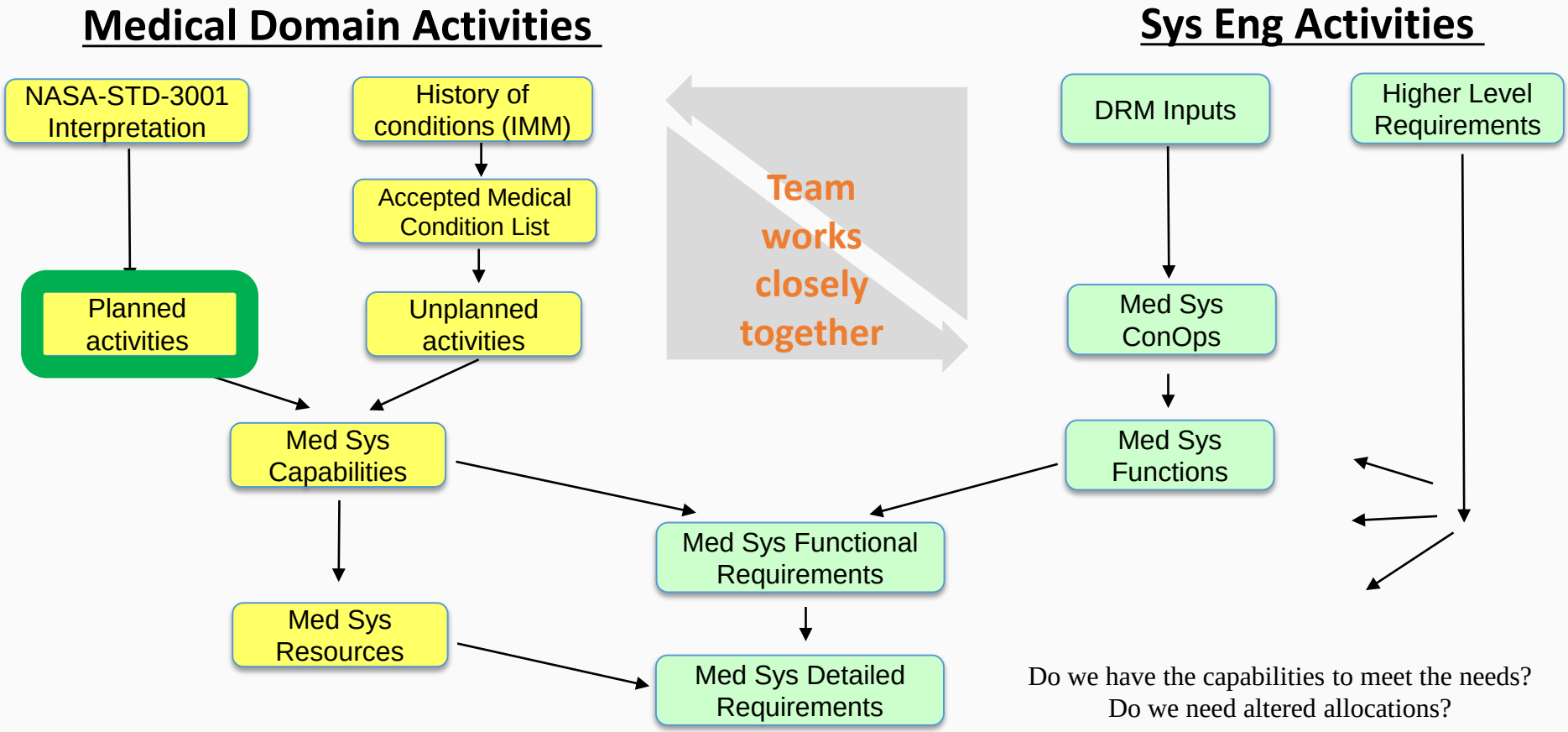
Medical Subsystem Of A Habitat CH&P System



ExMC Activities to get to Requirements



Planned Activities



Scheduled medical care that is expected or required to occur

Planned Activities – Methodology

- **Review of ISS Documentation - IDRD**
- **Mission Assumptions / Medical Care Philosophy**
  - DRM
  - Level of Care based upon ExMC interpretation of NASA STD 3001
  - ‘Program’ goals and objectives

Planned Activities

Scheduled medical care that is expected or required to occur

- Maintain crew health
- Monitor for potential contingency medical events
- Provide a test bed for future exploration missions

Examples

Planned Activities

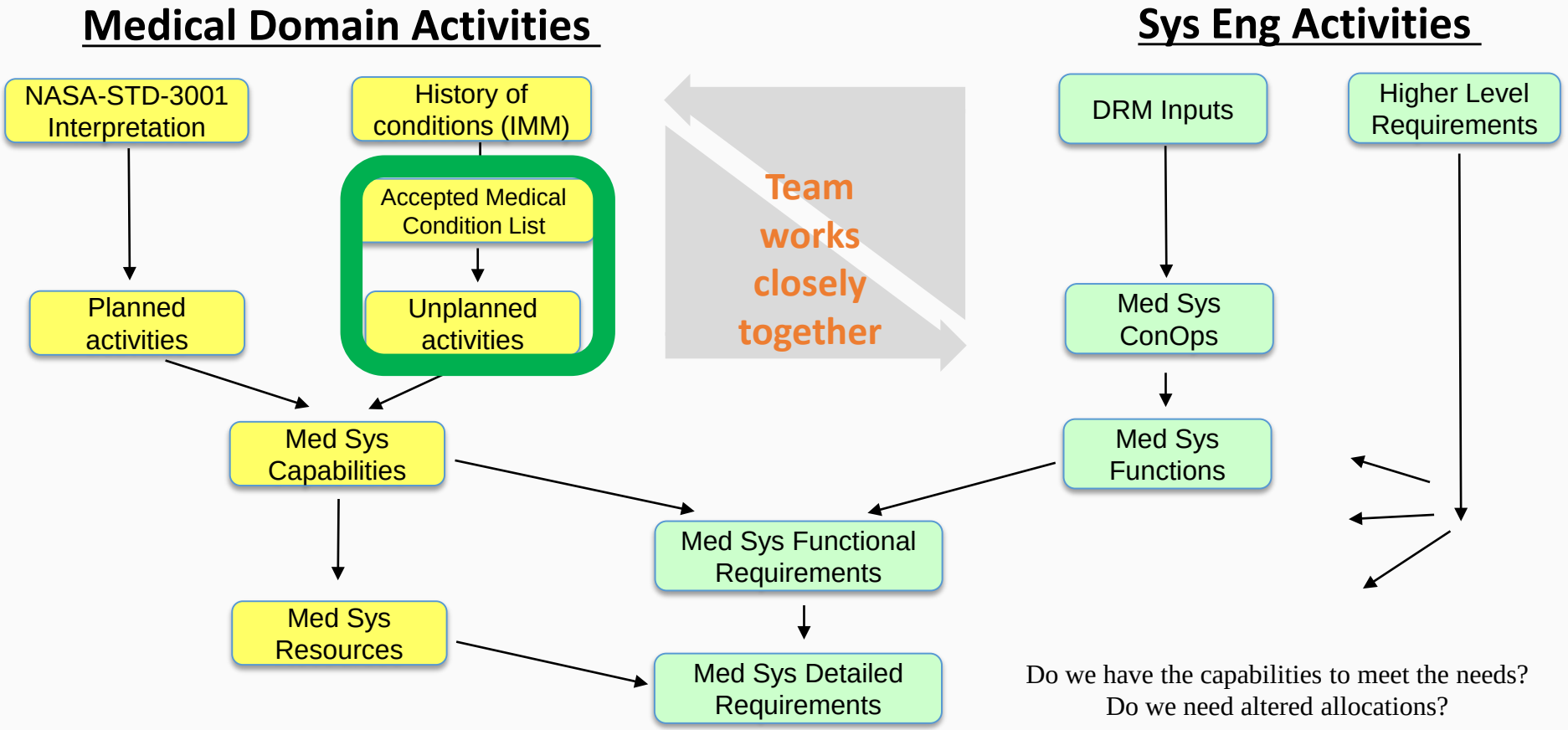
- Private Medical Conference
- Periodic Eye Exam

Testbed Planned Activities

- Periodic Dental Exam
- Bone Health Evaluation

Unplanned Activities

Team activities to get to requirements



Medical care not expected or required to occur but addressed on an as-needed basis

Accepted Medical Condition List - Methodology

- **Process uses list of conditions that influence mission planning**

- **ExMC started with the IMM Condition List**
  - Has evidence base and metrics that support the likelihood of occurrence
  - Each condition as defined by best case and worst case

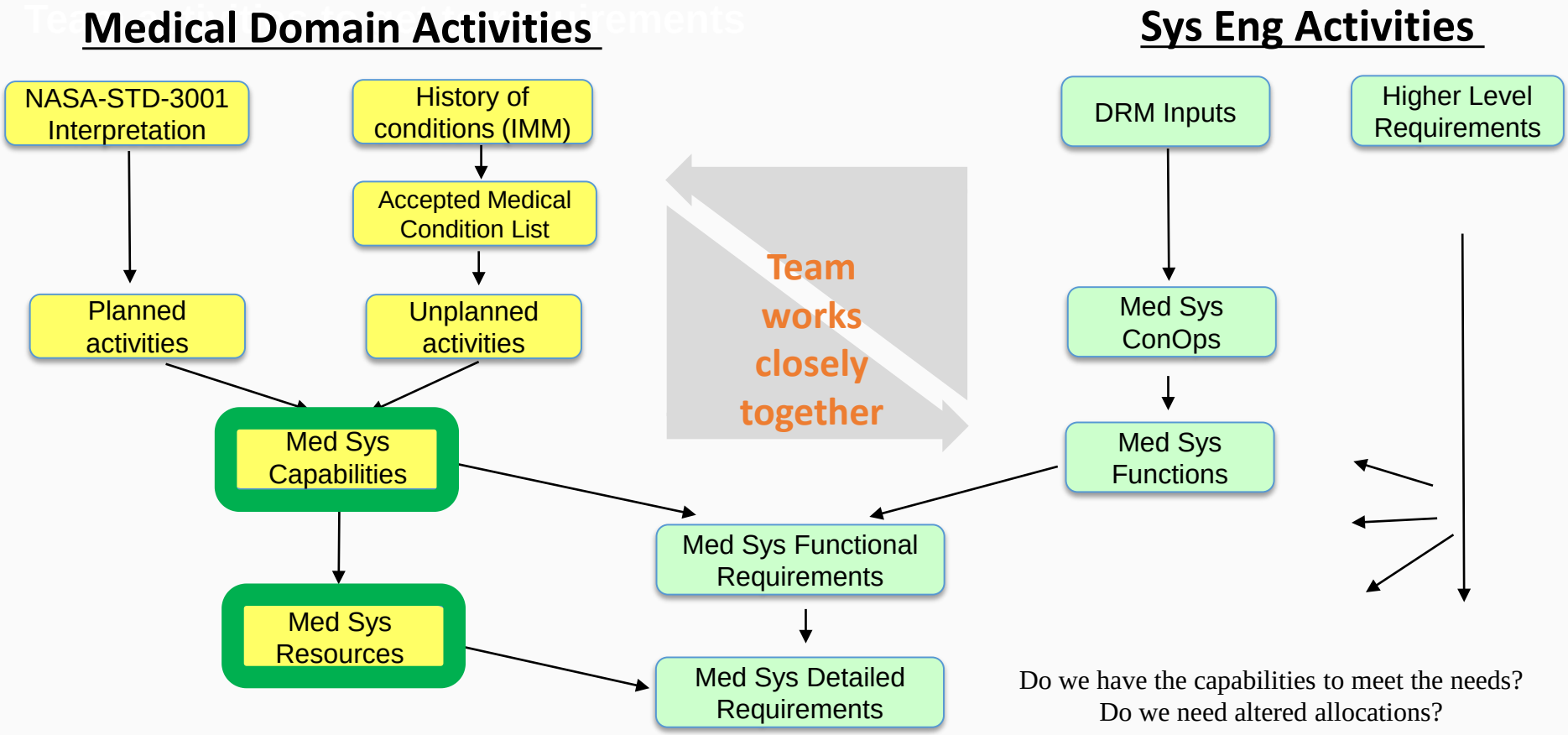
- **Process has stakeholders rank order list, thus providing context for discussion**
  - Probability of occurrence
  - Complexity score – Large # resources or difficult management
  - Futility score – likely to result in death or disability despite treatment

Source: Development of an Accepted Medical Condition List for Exploration Medical Capability Scoping, ExMC Working Group, July 2018

Accepted Medical Condition List - Example

Medical Condition	Best / Worst	Definition	Plan to Treat	Characterization
SKIN RASH	Best	The best case scenario is defined as mild to moderate and uncomplicated skin rash that responds to treatment.	Plan to Treat	N/A
SKIN RASH	Worst	The worst case scenario is defined as a moderate to severe skin rash, covering an extensive area and that might be refractory to treatment.	Plan to Treat with Conditions	Treat to best case only
SMALL BOWEL OBSTRUCTION	Best	The best case scenario is defined as an uncomplicated course of small bowel obstruction which responds to conservative medical treatment (antibiotics and symptomatic treatment) and involves relatively minor functional impairment.	Plan to Treat	N/A
SMALL BOWEL OBSTRUCTION	Worst	The worst case scenario is defined as having a complicated course of small bowel obstruction that is not responsive to conservative treatment and involves significant systemic symptoms, such as severe pain, such as fever, leukocytosis, tachycardia, elevated BUN, serum amylase or alkaline phosphatase, metabolic acidosis and a major functional impairment.	Plan to Treat with Conditions	Treat to best case, add antipyretics/pain control, IV fluids; consider medical evac

Capabilities and Resources



Action provided by a caregiver to address a condition or planned activity

Tangible and intangible assets used for a planned activity or condition

Capabilities and Resources– Methodology

- **Review existing documentation**
  - ISS Medical Kit contents list / Med Checklist
  - IDRD Annex 4
  - IMED database – resources
- **Medical Optimization Network for Space Telemedicine Resources (MONSTR) database**
- **Trace to planned activity and condition**

Capabilities and Resources

18 categories of capabilities, 165 unique capabilities

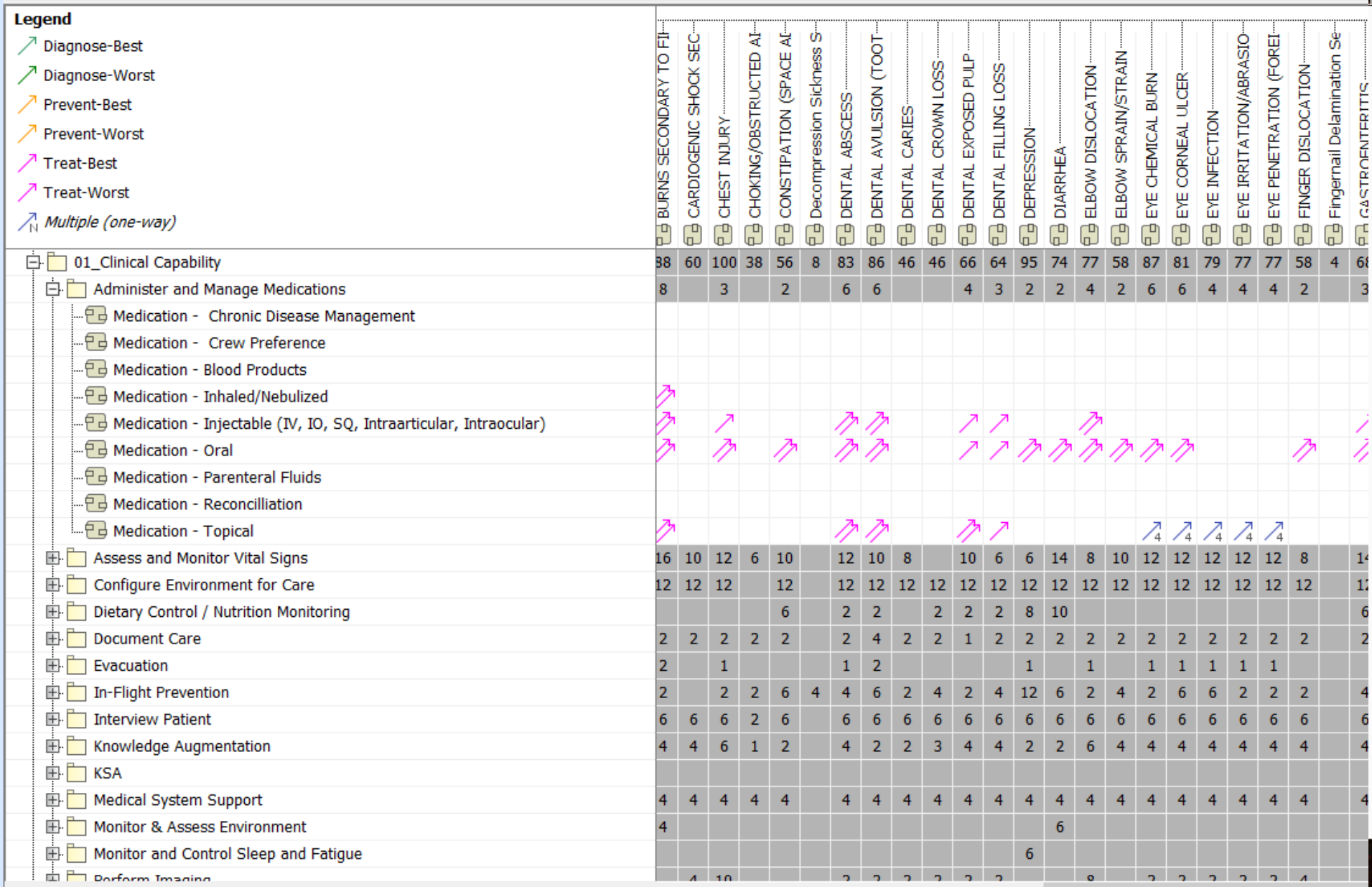
440 unique resources

Each Planned and Unplanned (condition) activity is traced to capabilities and resources using SysML model

Capabilities and Resources - Examples

Condition	Capability Category	Capability	Resources
DENTAL AVULSION (TOOTH LOSS)	Administer and Manage Medications	Medication - Injectable (IV, IO, SQ, Intraarticular, Intraocular)	EMR interface,Refrigerator,Needle (23G) 1.5",Needle [25g] 1.5",Syringe (3cc),Syringe (10cc),Syringe (5cc),Intraosseous Injection device,Bandaid (2x3),Bandaid Dot,Bandaid strip (1x3),Syringe (1cc Insulin syringe with SQ needle),PPE - Nitrile gloves (multiple sizes, pair),Sharps container, Biohazard Trash Bag,BZK wipes
DENTAL AVULSION (TOOTH LOSS)	Administer and Manage Medications	Medication - Oral	EMR interface, Potable water
DENTAL AVULSION (TOOTH LOSS)	Administer and Manage Medications	Medication - Topical	EMR interface,Refrigerator,Cotton swabs - sterile, Cotton swabs - clean, Cotton balls,PPE - Nitrile gloves (multiple sizes, pair),Biohazard Trash Bag

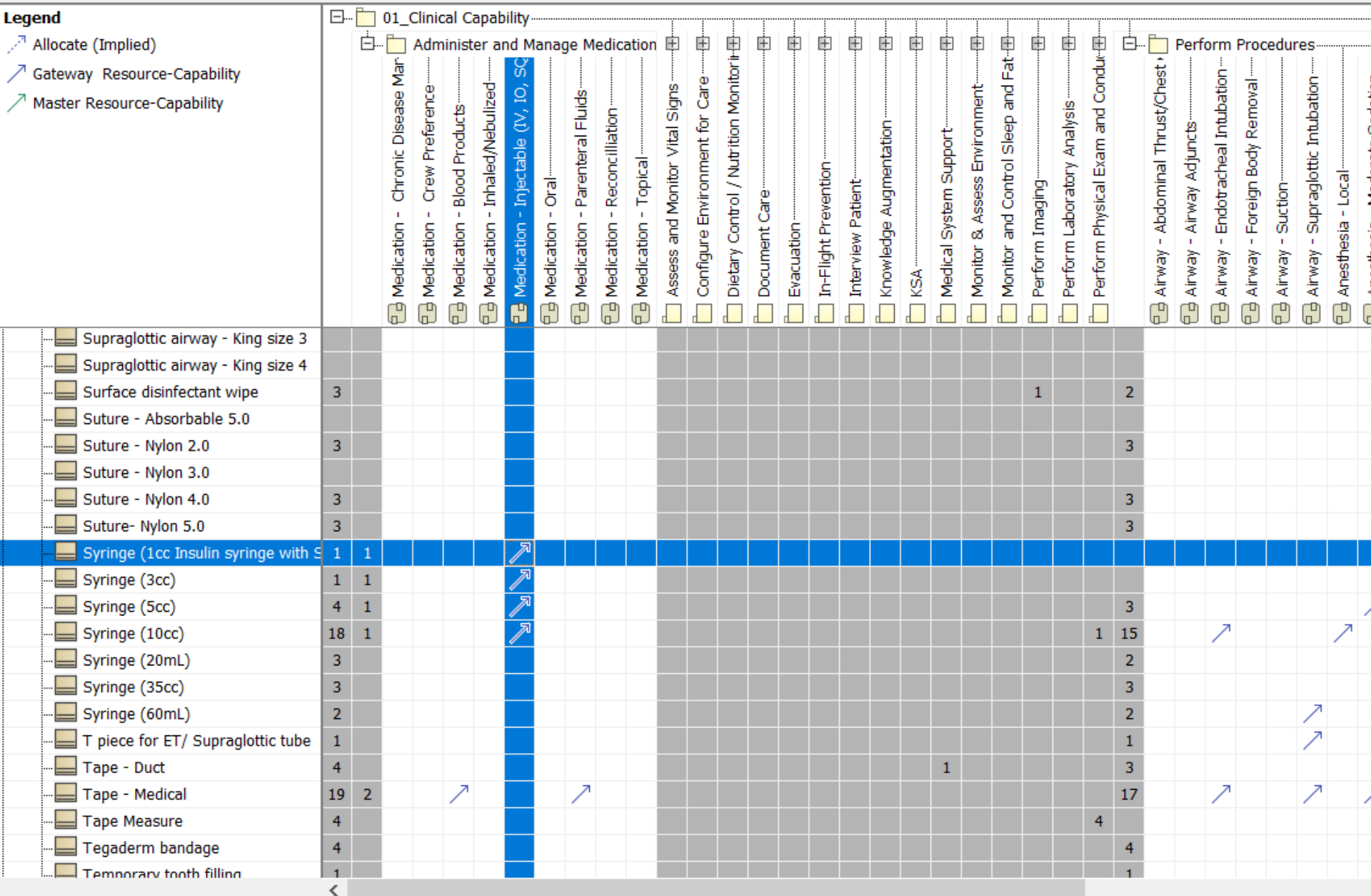
Medical Content seen in SysML model



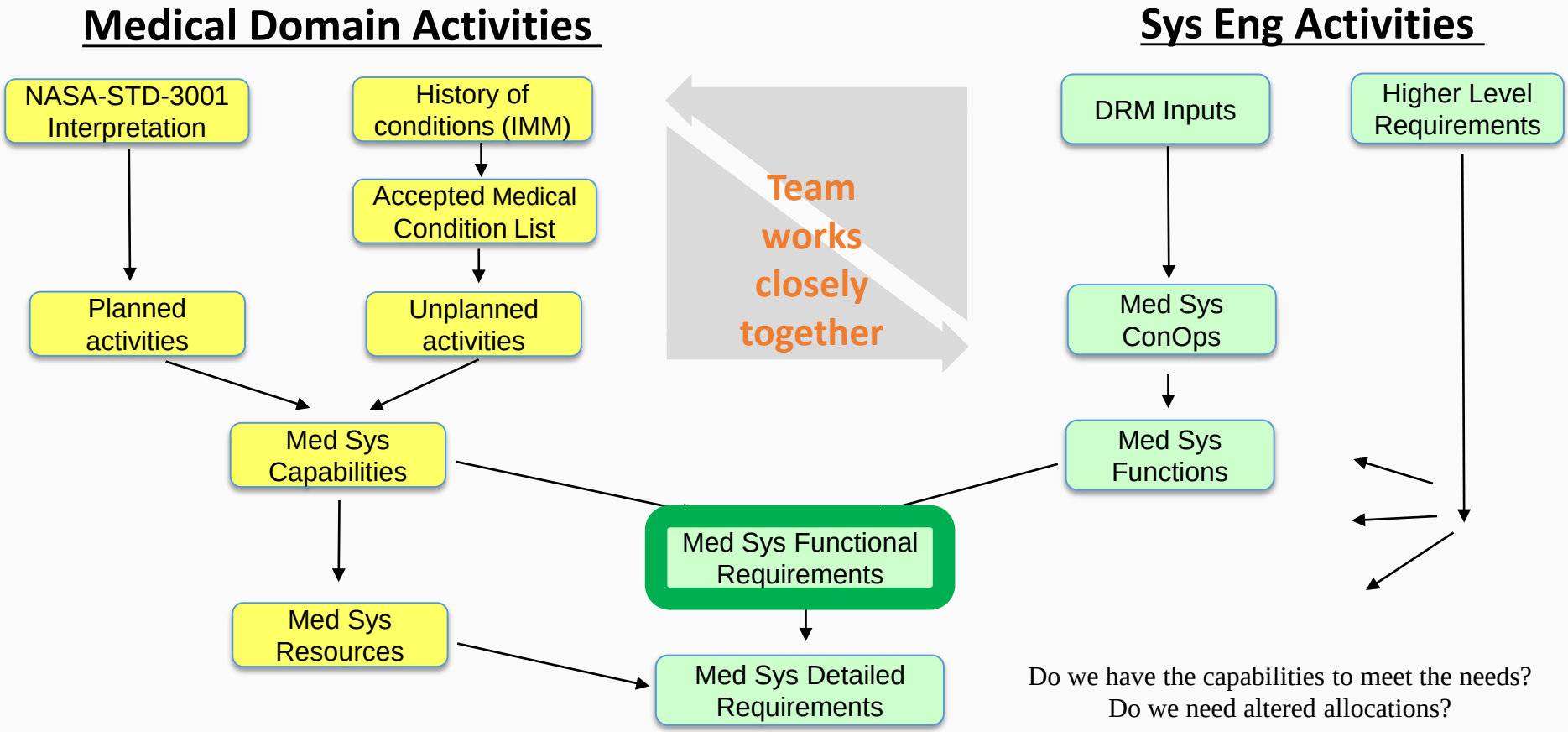
Capabilities and Resources - Examples

Resource	Capability
Syringe (10cc)	Airway - Endotracheal Intubation, Medication - Injectable (IV, IO, SQ, Intraarticular, Intraocular), Breathing - Needle Thorocostomy, Circulation - IO Access, Circulation - IV Access, GI/GU/Chest - Percutaneous drainage Bladder/Gallbladder/Appendix/Chest, Nose - Nasal Packing (Anterior + Posterior), GI/GU - Urinary Catheterization, Screening Exam/Test - Intracranial pressure, Wound Care - Repair, multiple layer, Wound Care - Repair, Single layer
Syringe (1cc Insulin syringe with SQ needle)	Medication - Injectable (IV, IO, SQ, Intraarticular, Intraocular)
Syringe (3cc)	Medication - Injectable (IV, IO, SQ, Intraarticular, Intraocular)
Syringe (5cc)	Medication - Injectable (IV, IO, SQ, Intraarticular, Intraocular),

Medical Content seen in SysML Model



Functional Requirements



Key Requirement Development Concepts

- **Type of requirements – project goal was high-level functional**
  - Functional – *what* has to be done
  - Performance – *how well* it has to be done, often quantitative
  - Interface – define in relation to external systems
    - e.g., mechanical, information, electrical
  - -ilities, operational, physical characteristics

In scope

Not in scope

- **Level of detail**
  - Starting point for this set is the clinical capability categories
    - Binned many individual capabilities to become lower level child requirements
    - Identified placeholders for higher level parent requirements

- **Content**
  - Single requirement can cover input from planned activities, testbed planned activities, unplanned activities, and functional decomposition content (based on ConOps)

Example Inputs to Requirements

Clinical Capability Listing example

DSG Clinical Capability Hierarchy										
DSG Activity Type	DSG Activity Name	Clinical Capability Category	Clinical Capability	Comments	Prevent Best	Prevent-Worst	Diagnose-Best	Diagnose-Worst	Treat-Best	Treat-Worst
DSG UnPlanned Activity	xxx	[illegible]	Image - ear				ACUTE SINUSITIS; B	ACUTE SINUSITIS; BAROTRAUMA (EAR/SINUS BLOCK); PHARYNG		
DSG UnPlanned Activity	xxx	Perform Imaging	Image - eye				ACUTE ANGLE-CLO	ACUTE ANGLE-CLOSURE GLAUCOMA; EYE CHEMICAL BURN; EYE		
DSG UnPlanned Activity	xxx	Perform Imaging	Image - integument				ACUTE COMPARTN	ACUTE COMPARTMENT SYNDROME; ANAPHYLAXIS; CHEST INJU		
DSG UnPlanned Activity	xxx	Perform Imaging	Image - intracavity				DENTAL ABSCESS;	DENTAL ABSCESS; DENTAL AVULSION (TOOTH LOSS); DENTAL C		
DSG UnPlanned Activity	xxx	Perform Imaging	Image - muscle				ACUTE COMPARTN	ACUTE COMPARTMENT SYNDROME; CHEST INJURY; ELBOW DIS		
DSG UnPlanned Activity	xxx	Perform Imaging	Image - soft tissue				ACUTE COMPARTN	ACUTE COMPARTMENT SYNDROME; ELBOW DISLOCATION; HIP		
DSG UnPlanned Activity	xxx	Perform Imaging	Image - vasculature				ABDOMINAL INJUR	ABDOMINAL INJURY; ACUTE COMPARTMENT SYNDROME; CHES		
DSG Planned Activity	Periodic Eye Exam	Perform Imaging	Imaging - Fundoscopy	may be unecessary if ISS proves out that OCT works for everyting this domain						
DSG Planned Activity	Periodic Eye Exam	Perform Imaging	Imaging - Optical Coherence Tomography							
DSG Testbed Planned Activity	HSI Assessment	Perform Imaging	Imaging - still/ video photography, external							
DSG Testbed Planned Activity	Periodic Dental Exam	Perform Imaging	Imaging - still/ video photography, external							
DSG Testbed Planned Activity	Periodic Physical Exam	Perform Imaging	Imaging - still/video photography, small spaces (ears, nares)	this is the only imaging we do on ISS (not counting SANS imaging needs)						
DSG UnPlanned Activity	xxx	Perform Imaging	Imaging - Ultrasound, Cardiac probe				ATRIAL FIBRILLATIO	ATRIAL FIBRILLATION/ ATRIAL FLUTTER; CARDIOGENIC SHOCK S		
DSG UnPlanned Activity	xxx	Perform Imaging	Imaging - Ultrasound, Doppler blood flow				ATRIAL FIBRILLATIO	ATRIAL FIBRILLATION/ ATRIAL FLUTTER; CARDIOGENIC SHOCK S		
DSG Planned Activity	Periodic Eye Exam	Perform Imaging	Imaging- Ultrasound, Linear probe							
DSG Testbed Planned Activity	Bone Health Evaluation	Perform Imaging	Imaging- Ultrasound, Linear probe							
DSG UnPlanned Activity	xxx	Perform Imaging	Perform Imaging Imaging - Image Ears				HEARING LOSS	HEARING LOSS		
DSG UnPlanned Activity	xxx	Perform Imaging;Image - Urinary Tract	Image - urinary tract				ABDOMINAL INJUR	ABDOMINAL INJURY; NEPHROLITHIASIS		

Requirements Organization

- **Provide Appropriate Level of Care**
- **Environment Configuration for Medical Care**
  - Configure Environment for Care
  - Habitat Medical Systems Inventory
- **Knowledge-Based Support for Crew Performing Medical Tasks**
  - Augment Crew Knowledge
  - Analyze Health Data
  - Data Presentation
  - Support Crew Performing Tasks
- **Crew**
  - Crew as Caregiver
  - Crew as Patient
  - Crew as Crewmember
- **Caregiver/Patient Interactions**
  - Interview Patient
  - Perform Physical Exam and Conduct Screening exams/tests
  - Assess and Monitor Vital Signs
  - Administer and Manage Medications
  - Perform Imaging
  - Perform Laboratory Analysis
  - Perform Procedures
  - Personal Protection
- **Medical Assessment and Monitoring**
  - Dietary Control/Nutrition Monitoring
  - Monitor and Assess Environment
  - Monitor and Control Sleep and Fatigue
  - Support Behavioral Health
  - Support Musculoskeletal Health
- **Maintaining Current State of Medical System**
  - Document Care
  - Update Habitat Medical System
  - Analyze Engineering Data
- **In-Flight Prevention**
  - Equipment Procedure
  - Exercise Protocol
  - Hygiene
  - Personal Protection
  - Radiation Exposure
  - Private Conference

Example of Applying Inputs from Clinical Capability Category

Clinical Capability Category: Perform imaging

Text

The Habitat Medical System shall perform imaging.

Rationale

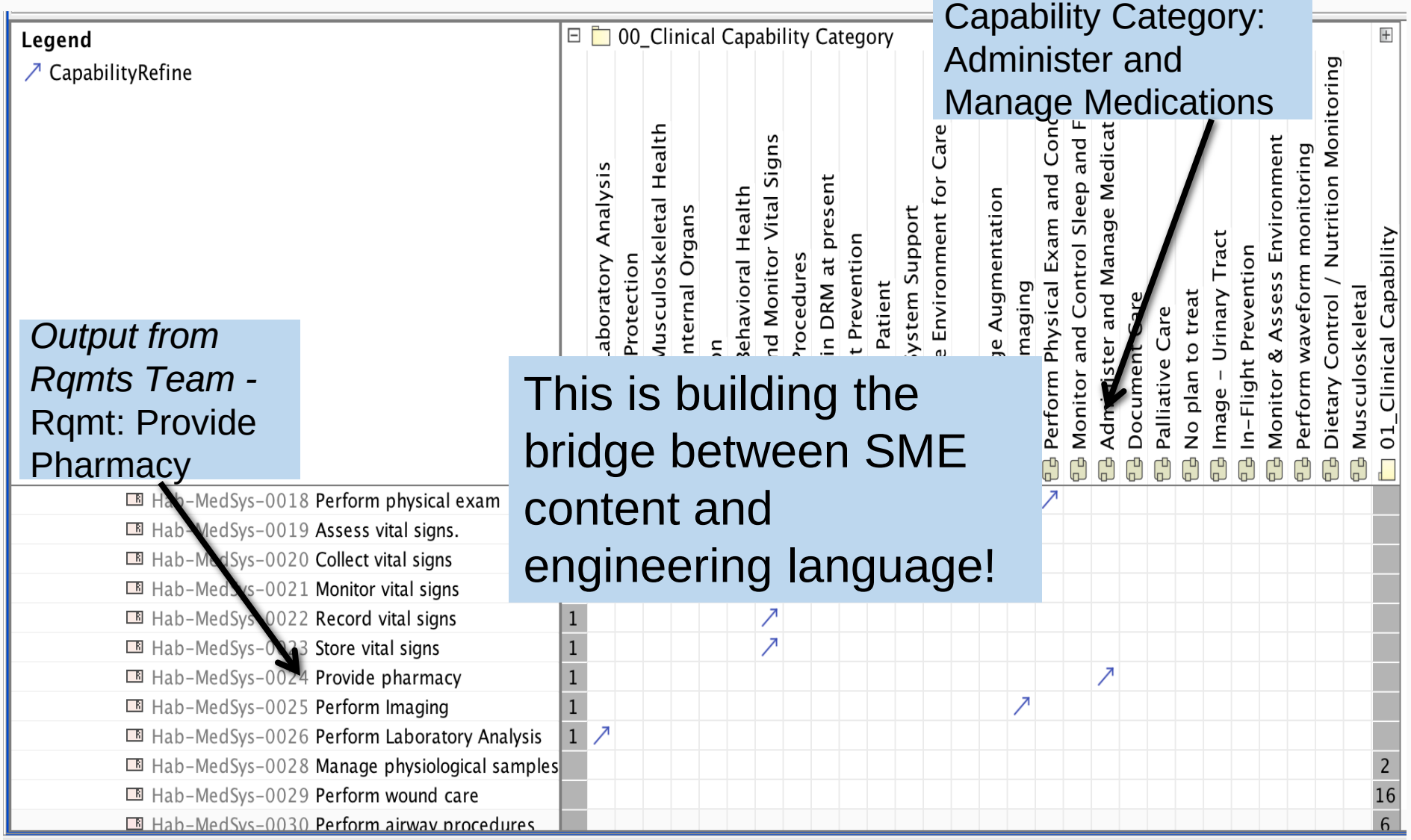
This capability supports the periodic eye exam planned activity, testbed planned activities such as physical exams, dental exams, and HSI assessments, and diagnosis and treatment of many medical conditions. Specific imaging modalities and target anatomical areas are specified at Level 5.

Imaging capability is essential for all medical aspects. This includes medical examinations for internal physiological health to surface physiological health.

Requirement Examples

ID	Name	Text	Rationale
Hab-MedSys-0024	Provide pharmacy	**The Habitat Medical System shall provide an in-flight pharmacy to the crew members**.	Pharmaceutical intervention and prevention, as provided by the in-flight pharmacy, is an essential component of risk management planning for crew healthcare during spaceflight. This includes prepare, administer, document, monitoring, inventory, analyze efficacy of med, titrate, or choose new medication if needed. Pharmaceutics assist crewmembers with adaptation to the spaceflight environment as well as help manage unexpected medical events that could occur, such as illness or injury. Types of medications needed are specified at Level 5.
Hab-MedSys-0005	Track medical inventory	**The Habitat Medical System shall track medical inventory**.	Ensure that medical inventory (supplies, equipment, and medications) is tracked at all times including when inventory is dispensed. Specific medical inventories, including quantities, availability, track history, etc., are specified at Level 5.
Hab-MedSys-0204	Perform genitourinary procedures	**The Habitat Medical System shall enable caregivers to perform genitourinary procedures.**	The medical system needs to provide capabilities (e.g., tools, technology, skills, medications) to perform genitourinary (GU) procedures (such as decompression of bladder). These procedures are needed for treatment of conditions such as urinary retention. Types of GU procedures are specified at Level 5.

Requirements Relationships to Discipline Inputs

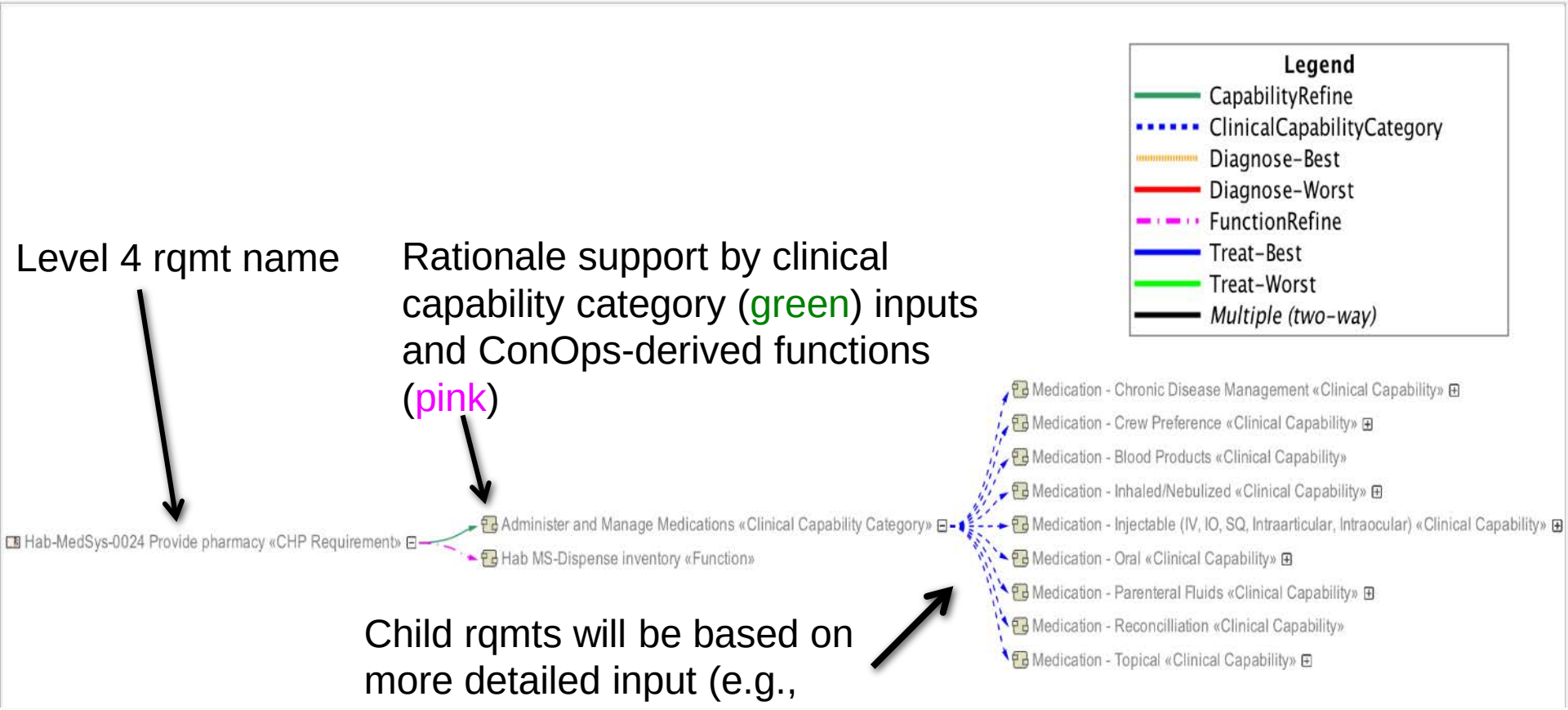


Input from clinicians - Capability Category: Administer and Manage Medications

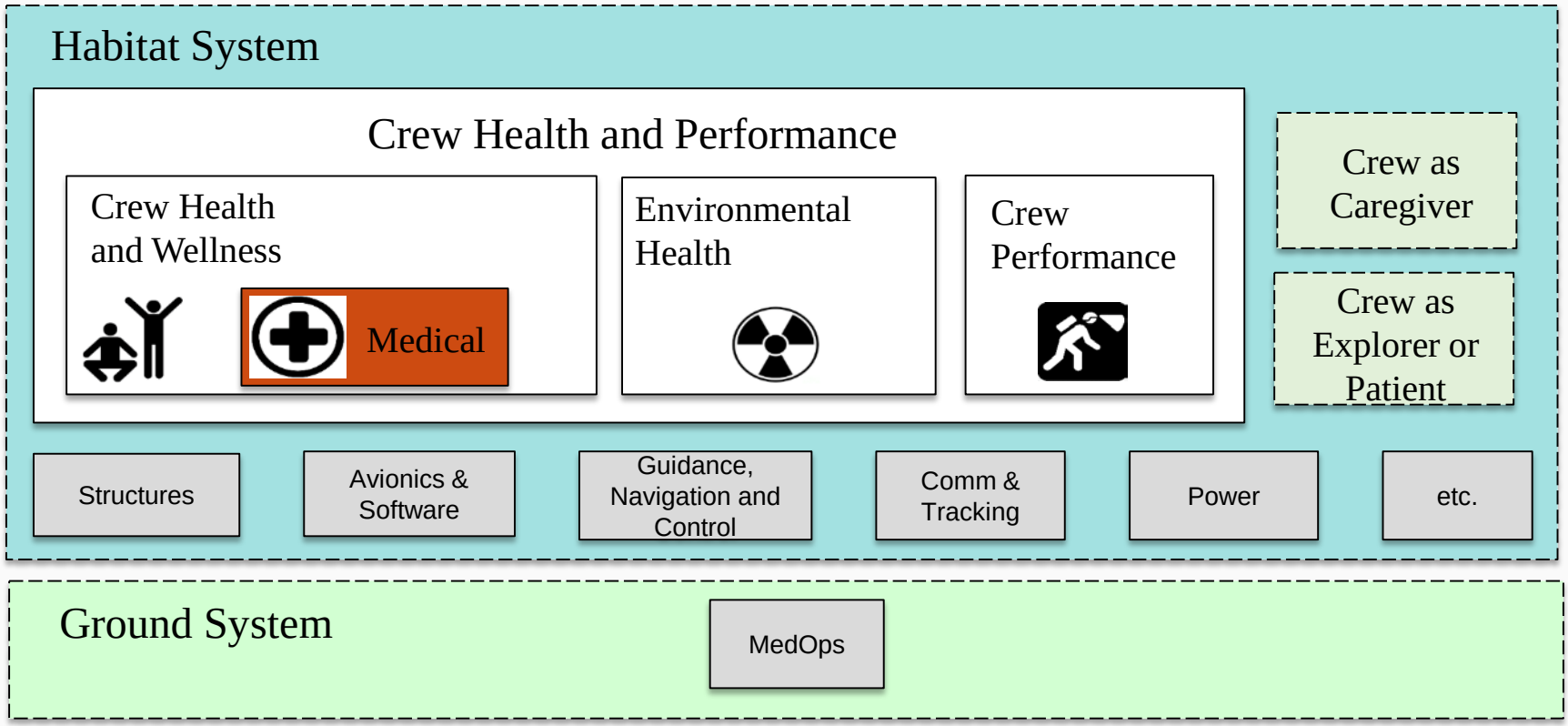
Output from Rqmts Team - Rqmt: Provide Pharmacy

This is building the bridge between SME content and engineering language!

Visualizing the Substance Behind Requirements

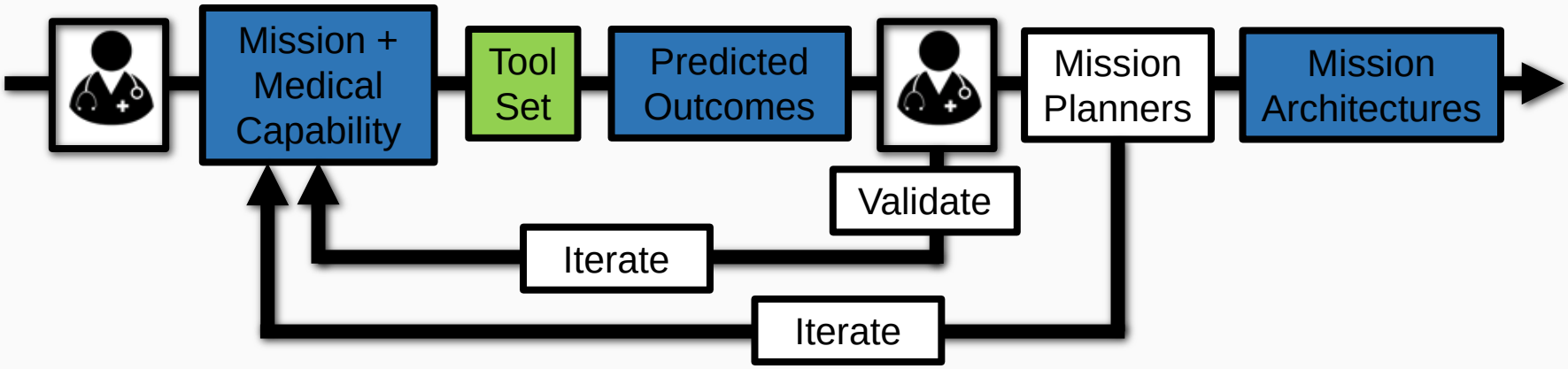


Collaborations

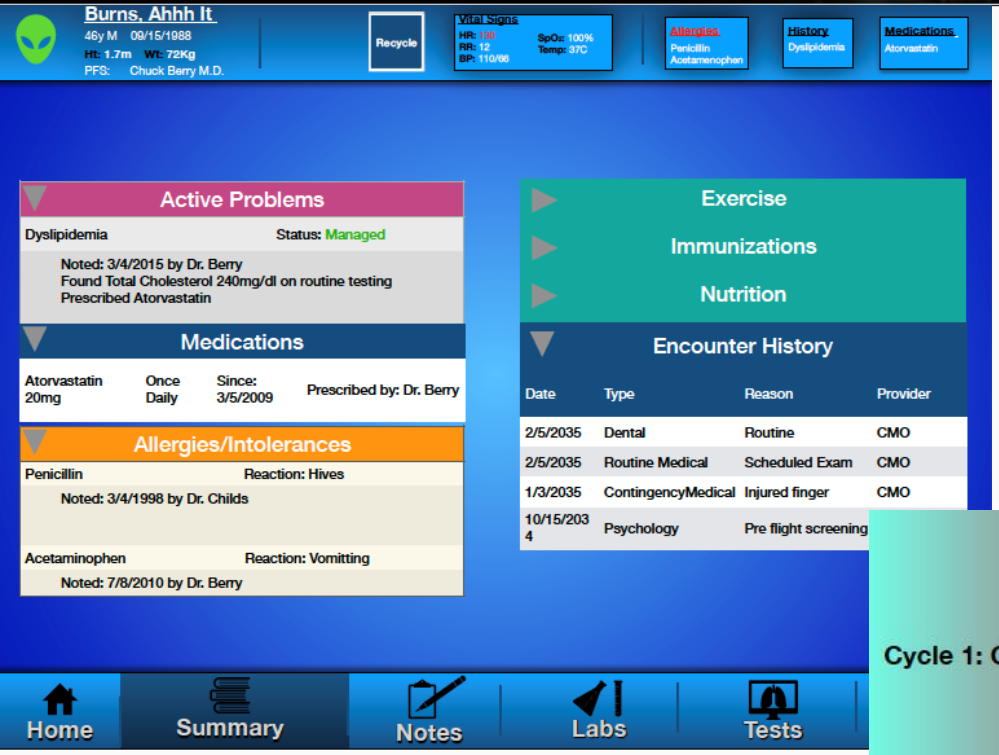


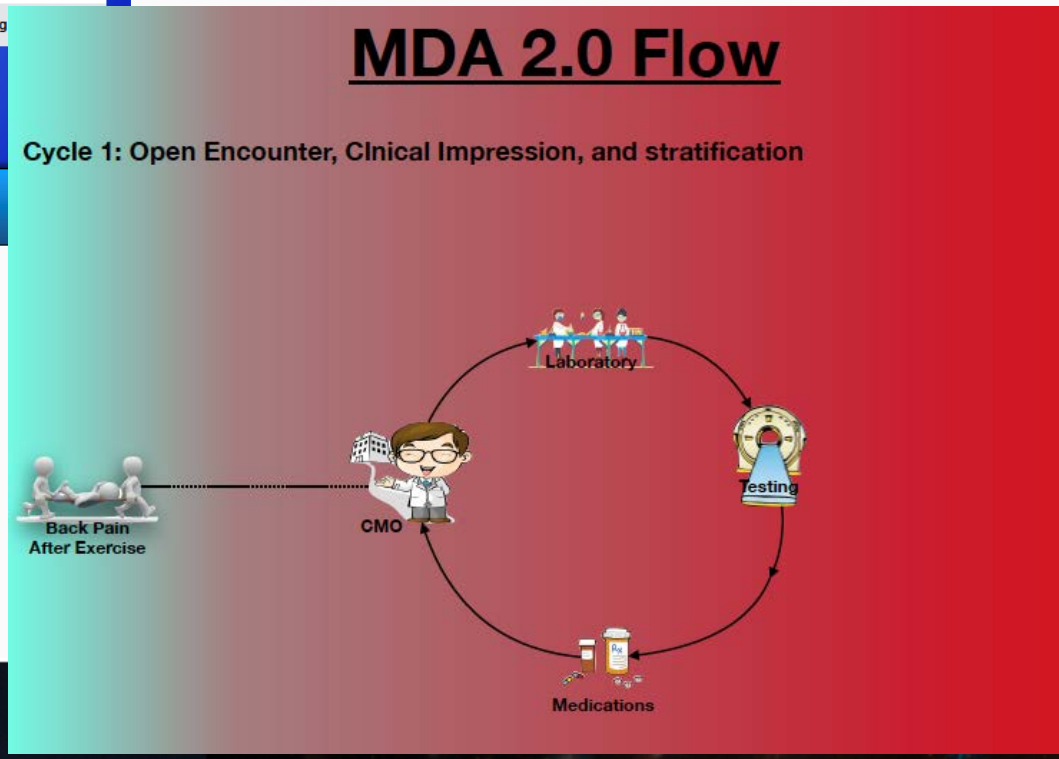
Collaborations – Trade Space Tool Suite

Provide a means for the medical community's and crew's interests to be represented during deep space mission development to quantify the mass, volume, power impacts, and risks that a potential medical capability could have on crew health outcomes to inform medical capability in context of mission architectures

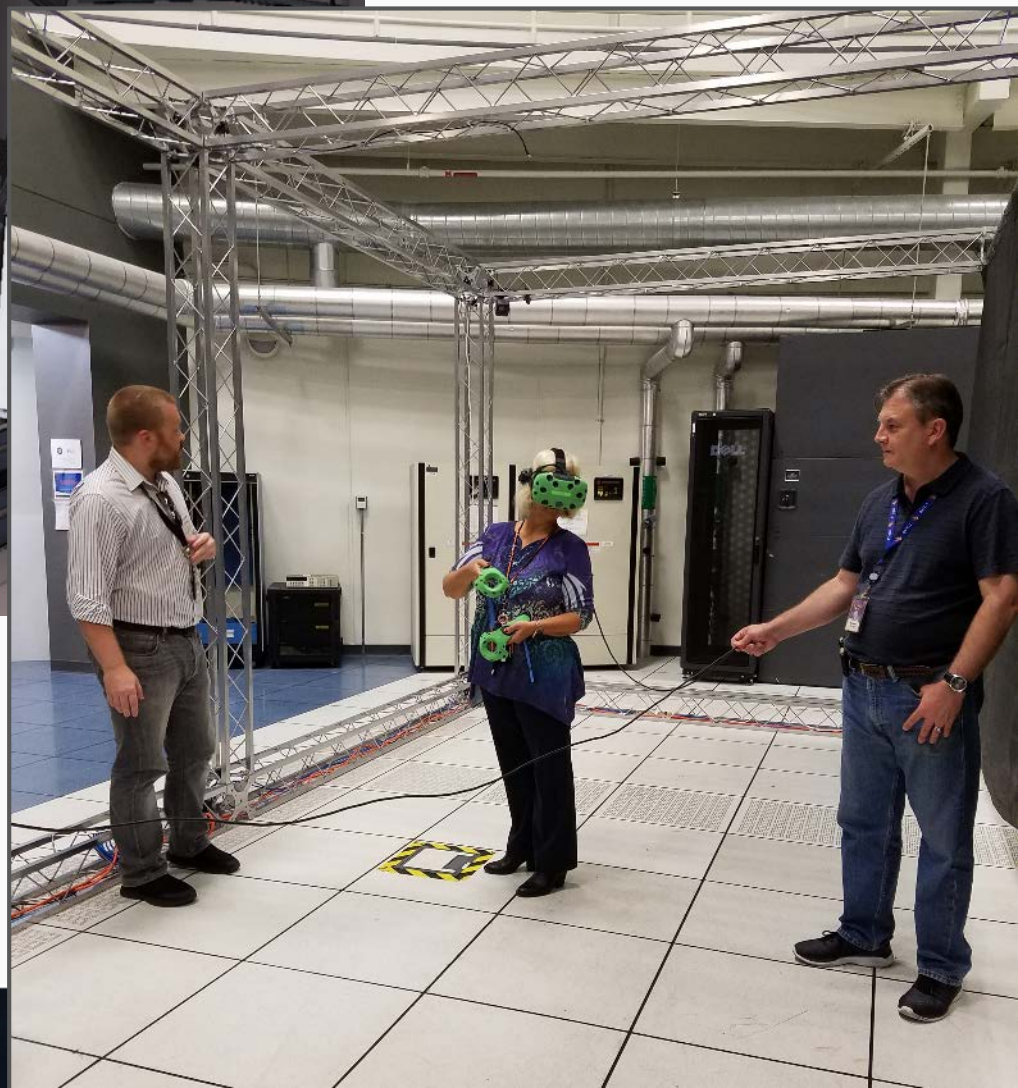


Collaborations – Medical Data Architecture

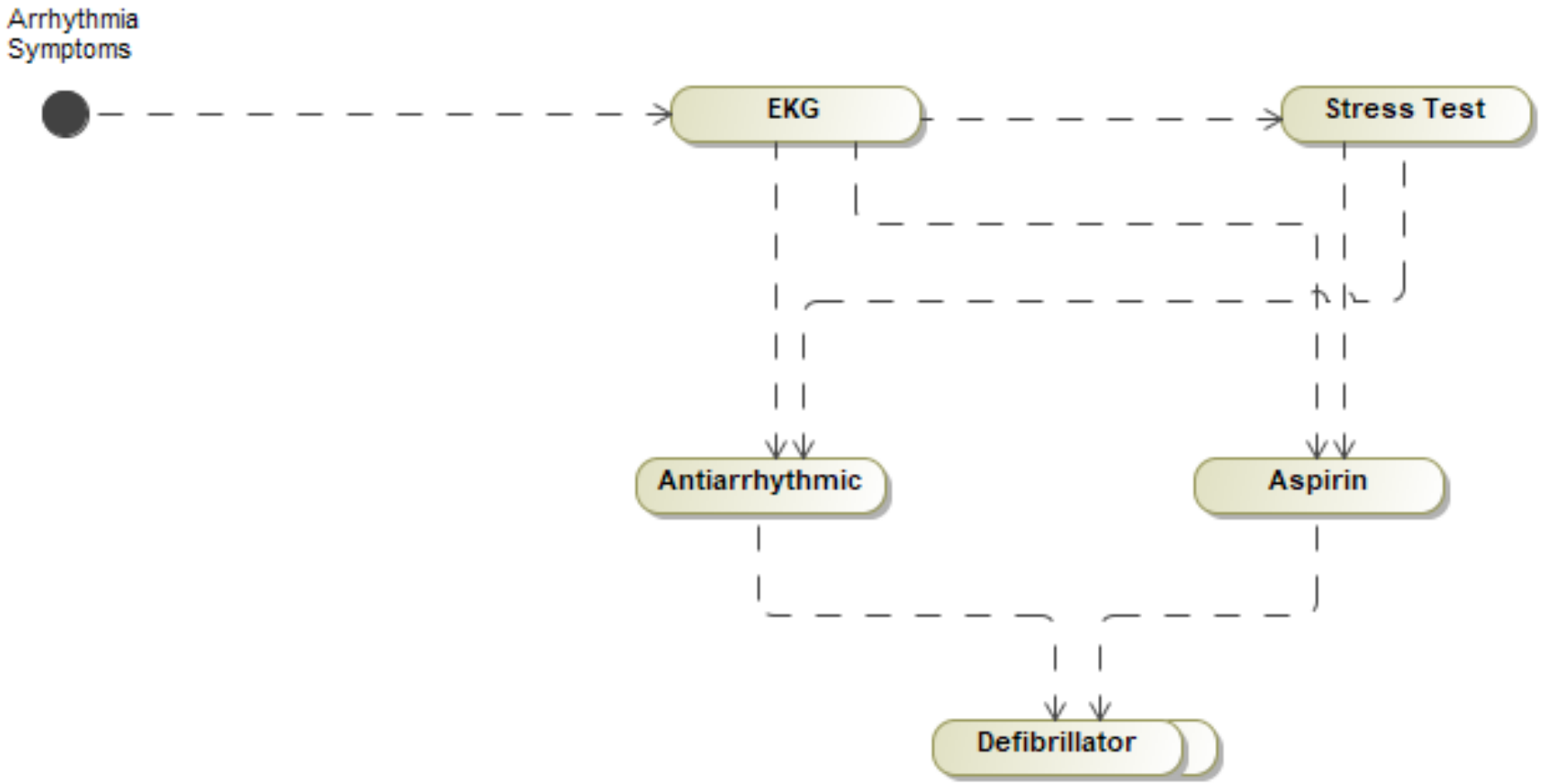




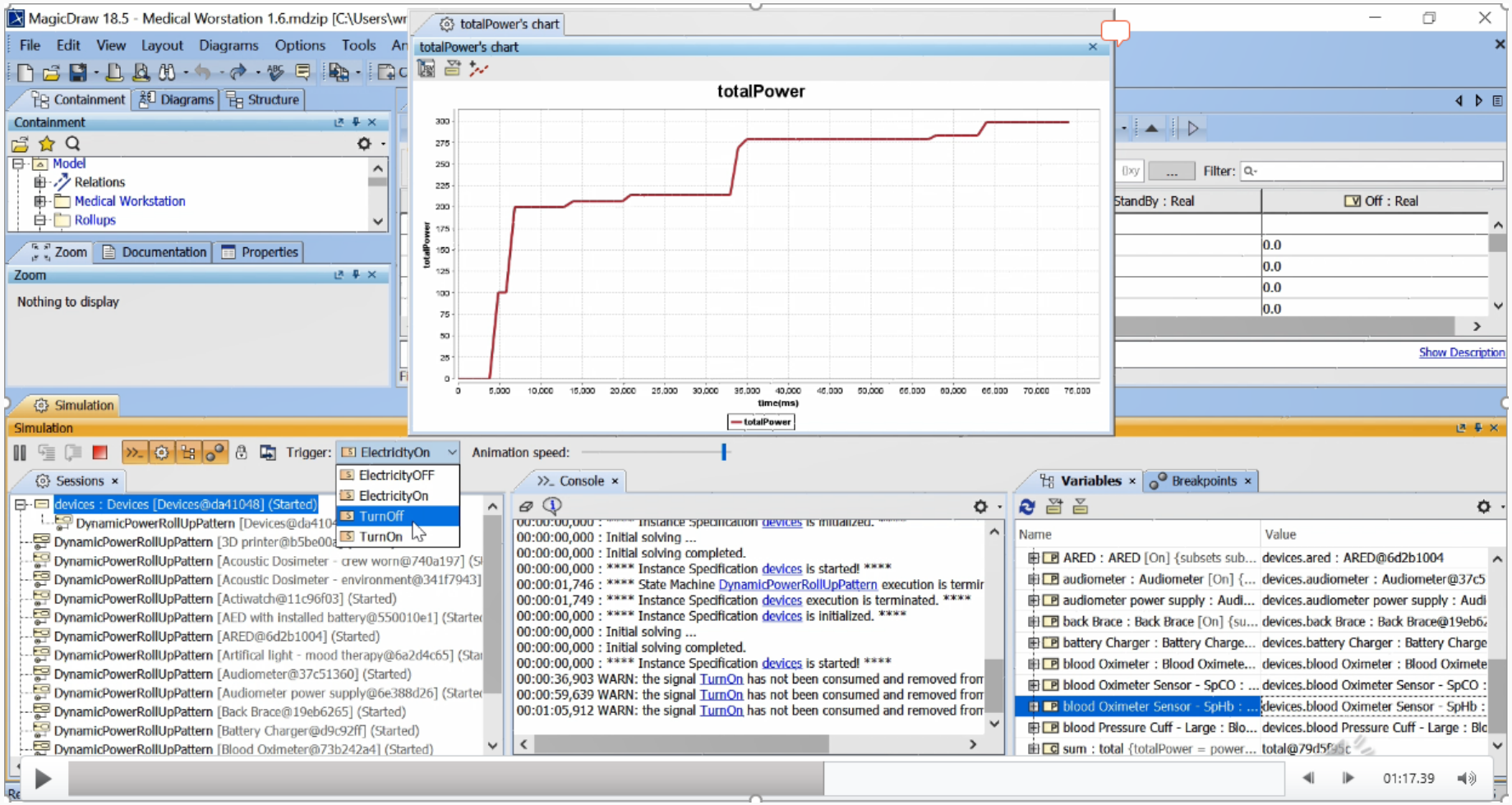
Collaborations - Medical Workstation



Collaborations - Power Calculation



Collaborations - Power Calculation



Summary

Build a bridge between engineering and medical domains and developed a common language

Established processes and products to integrate between medical and exploration programs

Provided notional content for a medical system that can be used to inform initial Gateway planning

Questions?

Thank you!

BACK-UP SLIDES